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CSERIAC GATEWAY

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CSERIAC is a United States Department of Defense Information Analysis Center administered by the Defense Technical Information Center, Alexandria, VA, managed by the Human Engineering Division, Armstrong Laboratory, Wright-Patterson Air Force Base, OH, and operated by the University of Dayton Research Institute, Dayton, OH.

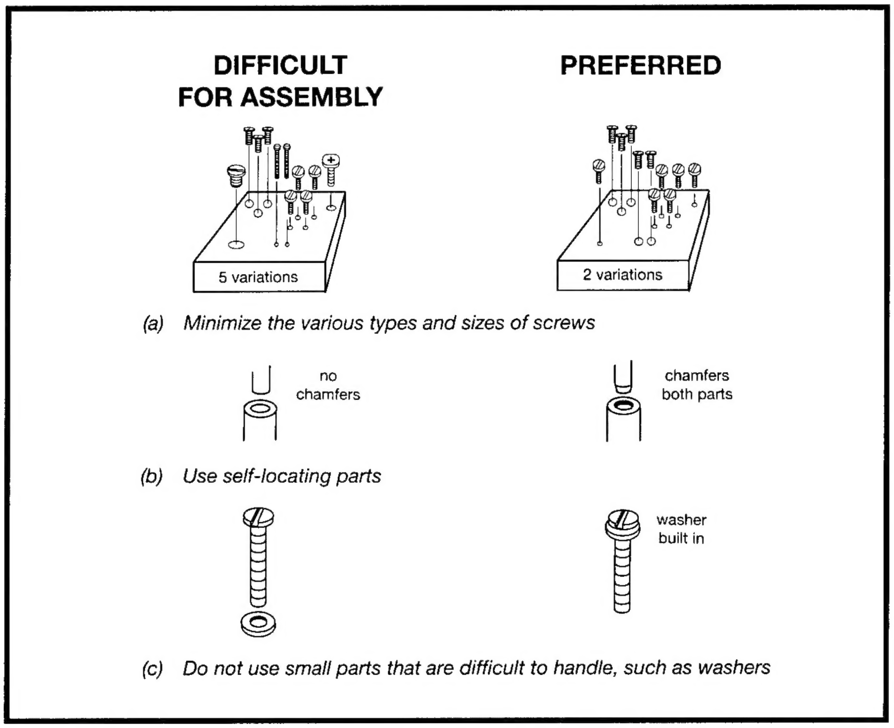

Figure 1. Principles used to design for automation also simplify human assembly. (Adapted from Helander & Nagamachi, 1992)

Automation and Human-Computer Interaction in Manufacturing

Martin Helander

During the 1980s, General Motors invested $80 billion in automated manufacturing. Automation and robotics were fairly new as a concept, and it was seen by U.S. industry as the savior of competitiveness. According to an article in *The Economist* (August 10, 1991) about $20 billion was lost since the automation did not prove entirely effective. Most other large industries had similar experiences; losses and early write-offs were often greater than 25%. At the time, there was over-reliance on technology. Many implementation problems, such as task allocation, training, vertical and horizontal task expansion, were not successfully addressed.

The introduction of robots for assembly had an interesting effect on product design. Robots are typically not equipped with vision (because it is too expensive) and they have poor finger dexterity. To make assembly possible, product design had to consider many special requirements such as "Incorporate washers with screws," "Use chamfers on holes and pins to

Continued on page 2

increase the target area," "Use symmetrical parts, so that they don't have to be turned around," "Use, at most, two sizes of screws," and "Use snap and insert assembly."

As a result, product design changed radically. It came somewhat as a surprise that the identical changes also greatly facilitated manual assembly—to the extent that there was no true advantage in using robots (see Fig. 1). The great irony of this development is that it took robots to realize that human assembly work can be simplified.

Product designs create jobs on the manufacturing floor, and there are now opportunities to design products that are easy to assemble, improve work posture, reduce product weight and ease manual handling, introduce a variety of work responsibilities, reduce safety hazards, and maybe even improve job satisfaction (Helander & Furtado, 1992; Nagamachi & Yamada, 1992).

Today, manufacturing depends on machinery and automation for many processes such as surface treatment, milling, and cutting. However, when it comes to assembly there is not necessarily an advantage. The versatility and adaptability of human labor is so great that automation does not always pay off. A printer assembly line at the IBM plant in Charlotte serves to illustrate the point. In 1984, after several product modifications, it was changed from an automated system to a manual labor one.

Computer-Aided Design and Computer-Integrated Manufacturing

Despite our reservations concerning automation, computers remain useful for product design and manufacturing planning. Computer-aided design (CAD) terminals were first used as substitutes for drawing boards, and this application has proven very useful. Elements of a drawing can also be subjected to computer-aided engineering (CAE) analysis (e.g., finite element analysis) and instructions for manufacturing that are implicit from a drawing can be transferred to numerical control (NC) machines and robots.

In concurrent engineering, computer modeling of manufacturing has become even more strategic. It used to be that a product designer would finish a design and then hand it over to a process designer who would design the manufacturing process. Such a step-wise procedure produces a sub-optimal solution. In concurrent engineering, product and process designers jointly design a product satisficing several criteria (see Table 1). This saves time and reduces costs.

With this scenario, the knowledge base for design must expand—to the extent that corporate strategic planning is affected. Design must involve a variety of professionals with CAD being transformed into Computer Supported Cooperative Work (CSCW). But there is an alternative scenario: my colleague, Roland Ortengren (1992) predicted that 90% of ergonomic requirements in product design can be handled by individuals without professional training in ergonomics. If so, maybe a single but resourceful "super designer" could do the job guided by expert systems.

The use of CSCW brings many intriguing questions related to communication style and collaboration. How can individuals negotiate and trade-off design solutions? Maybe one can rely on computer support! For example, Questions, Options, and Criteria (QOC) (MacLean, Young, Bellotti, & Moran, 1991) is a software system which documents design criteria, options for design, and solutions.

Computer-integrated manufacturing (CIM) is difficult to implement. Siemieniuch (1992) told the horror story of a £9 million project which set out to design a "user-friendly" CIM system. But the project failed, since the various pieces of software were not well integrated. A critical element in this failure was the lack of strategic planning and testing of typical work activity scenarios.

In proposing a solution to integration of software, there is a fundamental problem. There is not yet a credible theoretical framework for task allocation in human-computer interaction. Upmann (1992) suggested that tasks demanding and promoting human skills, such as planning, assessment, development of solution strategies, heuristics, and rational thinking, should be reserved for the user. The computer should relieve the user of routine work such as "ordering," "searching for," and "out-putting data." This proposal may be too simplistic, how-

Table 1.
Criteria in Concurrent Engineering

- Ease of assembly
- Low-cost manufacturing process
- Product maintenance
- Visual inspection
- Worker and user safety
- Product usability and aesthetics
- Packaging and transportation
- Clean manufacturing
- Reusability of parts and disassembly
- Parts commonality

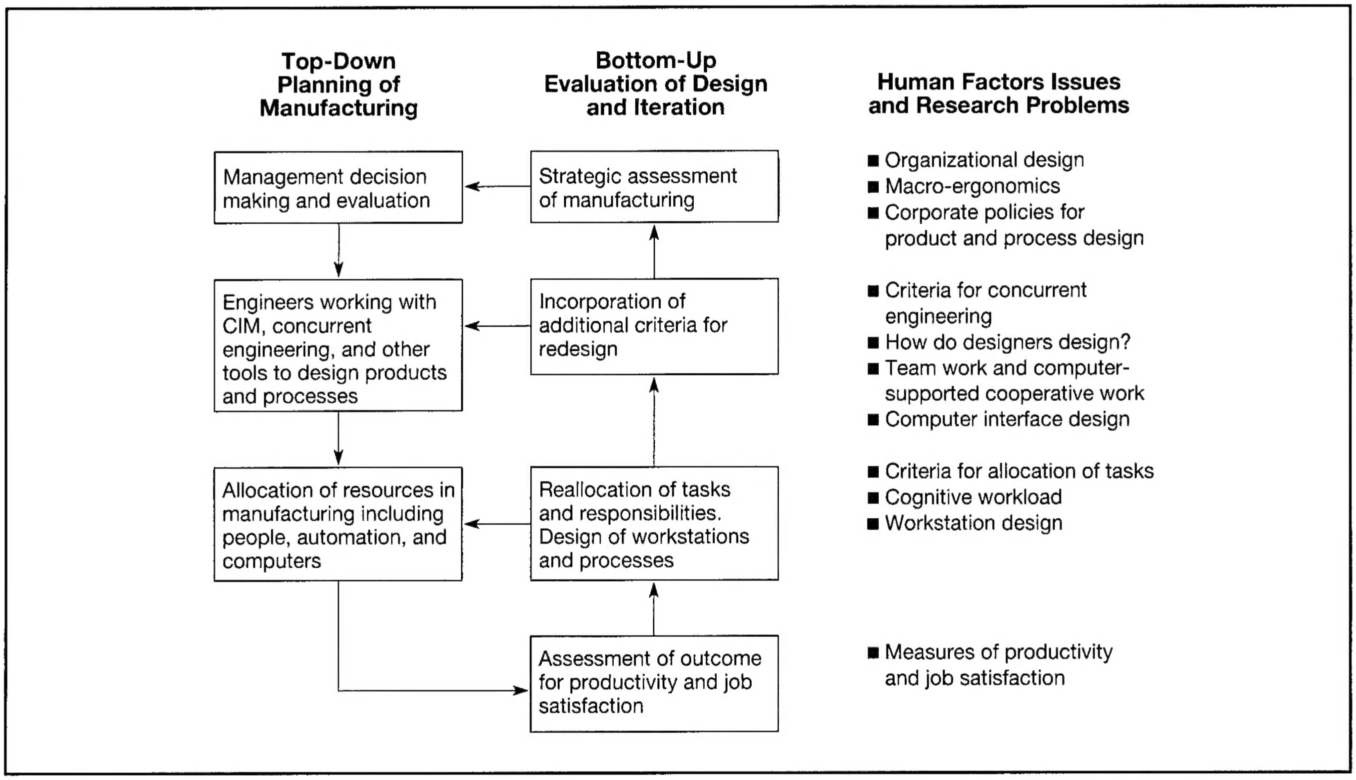

Figure 2. Manufacturing may be configured as a feedback system with top-down planning and bottom-up evaluation.

ever, since computers can overcome many of the limitations and biases that humans display in decision making. In addition, Upmann's suggestion does not solve the problem of "fluency" in dialogue or interchange of knowledge between the computer and user. There are many fundamental cognitive issues in human-computer communication: style of reasoning and critiquing, sharing of goals and partial solutions, development of mutual responsibilities in command-control, and adaptivity (who is the leader—and when?). Moreover, a valid nomenclature of human-computer task allocation is still missing, and experimental evidence is far away.

Organizational Impact

CIM is also used for day-to-day planning in manufacturing. In modern small-batch manufacturing, there are needs for computational planning of resources and scheduling of jobs among machines. (Actually both of these issues could also be incorporated in concurrent engineering.) Typically, computational planning is handled by a system such as Manufacturing Resource Planning (MRP) II (Rindom, 1992). Modern, small-batch manufacturing requires continuous decision making based on feedback from the operation itself—rather than the typical feed-forward which is implied by management orders, centralized plans, and schedules. These computations should not necessarily be performed by an engineer or supervisor, however. In this turbulent environment, Rasmussen (1992), for instance, has asserted that planning and control are best exercised from the shop floor. Put a computer on the shop floor, and the worker will do it. Thus the introduction of computer support has implications for manpower planning and decentralization of decision making. The greater the uncertainty in planning, the greater is the organization's need to rapidly respond to change. This requires a high degree of professionalism, independence, and flexibility of employees, particularly those on the shop floor.

The Need for Research

Figure 2 summarizes many of the needs for human factors research that are implicit from this article.

The left portion of Figure 2 illustrates that product design carries implications for allocation of resources, including task allocation between agents. The design is then assessed with respect to a multitude of concurrent criteria (in Fig. 2 just two are noted: productivity and job satisfaction). If the outcome of the assessment is unsatisfactory, there is a design iteration. Product design is changed, which changes task allocation, and so forth. When all criteria have been satisficed there are straightforward implications for design of work-stations and processes. In the right portion of Figure 2 several research issues are noted.

As DeKeyser (1992) has observed, there is a great need for field studies in automated manufacturing. Highly pertinent cognitive and socio-technical issues cannot be studied well in the laboratory environment. Parsons (1992) noted that since the Hawthorne research at the Western Electric plant around 1935, no other field study in the U.S. has been as pioneering and influential. He asked, "Is something

Continued on page 4

wrong with American industry that more than five decades have passed without a research enterprise equivalent in scope to investigate the impact of new automation and technology?" Given the tremendous influence that these capabilities have already had on manufacturing processes and the marked, ever increasing power to bring about even greater change, it seems the time is right to initiate such efforts.●

Martin Helander, Ph.D., is a Professor of Industrial Engineering at the State University of New York, Buffalo, NY.

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COTR Speaks

Reuben L. Hann

Is automation the solution to all production problems? It seemed for a while that might be the case. But as Dr. Martin Helander, State University of New York, points out in his feature article on "Automation and Human-Computer Interaction in Manufacturing," there are pitfalls with automation. Sometimes manual methods are better than automated methods. To learn more about the intricacies of automation and manufacturing, read this article which Martin based on his highly successful presentation as part of the 1993 Human Engineering Division, Armstrong Laboratory Colloquium Series: The Human-Computer Interface.

Another speaker from that series, Dr. John Stern of Washington University, spoke on "The Eyes: Reflector of Attentional Processes." Dr. June Skelly, from the Crew Systems Integration Branch in our division, provides a synopsis of his presentation; it is accompanied by an edited transcript of a conversation that I had with John during his visit.

Last spring, the Human Engineering Division of the Armstrong Laboratory hosted a workshop on Electronic Imaging of the Human Body. Jennifer Whitestone, Design Technology Branch, Human Engineering Division, details the mission of the workshop in this issue. Twenty-three invited speakers presented papers on a variety of topics related to this area. These have been collected in a single volume which is available through CSERIAC for $35.

Collecting data through surveys, questionnaires, and interviews can often be a challenge. However, the staff at Bernier & Associates have made that task easier through the development of a software program, INFORUM. Leo Bernier has provided an overview of INFORUM and some of its features. For example, it can collect data from different people in different locations at different times! This flexibility in data collection allows for broad participation, without the expense and aggravation. And this is only one of its features!

After more than four years as the Associate Director of CSERIAC, Dr. Larry Howell has moved on to other duties at the University of Dayton Research Institute. While Dr. Howell was at CSERIAC, the organization grew from an initial four-person operation to a staff of 25; during this same period, the revenues doubled every year.

Dr. Howell is succeeded by Mr. Don Dreesbach who has led CSERIAC's technical area task management since January 1992. Mr. Dreesbach has a distinguished Air Force career, including operational flying and laboratory directorate management, as well as a number of years of contract technical management. We offer our best wishes to both in their new positions! ●

Reuben "Lew" Hann, Ph.D. is the Contracting Officer's Technical Representative (COTR) who serves as the Government Manager for the CSERIAC Program.

Announcements

BCPE Certification Requirements Revised

The Board of Certification in Professional Ergonomics (BCPE) has revised its certification requirements for ergonomists and human factors professionals. Starting January 1, 1994, certification criteria will be (1) a master's degree in ergonomics/human factors or equivalent educational background; (2) four years of full-time professional practice in ergonomics with an emphasis on ergonomic design; (3) submission of a work product demonstrating the application of ergonomics to a product, process, or environment; and (4) a passing score on a written certification examination administered by the BCPE.

Previously, however, experienced practitioners were certified under a "waiver of examination" procedure, for which the minimum requirements were a master's degree in ergonomics or a closely related field and seven years of demonstrable experience in the practice of ergonomics. Applications are available for $10 and the application processing fee is $200 (to which the $10 application fee may be applied), and the annual renewal fee is $75. For further information or an application, please contact:

BCPE
Office of the Executive Director
P.O. Box 2811
Bellingham, WA 98227-2811
Telephone (206) 671-7601, fax (206) 671-7681

Human Factors and Ergonomics Society Placement Service

The Human Factors and Ergonomics Society (HFES) offers an opportunity for employers seeking human factors/ergonomics expertise to tap into the tremendous knowledge base and range of experience of HFES members and other professionals in related fields.

Candidates are computer-matched with available jobs on the following criteria:

Highest degree held
Major field of study

GATEWAY

Years of experience
Salary
Areas of interest
Employment sector
Geographical Area
Type of position

The HFES Placement Service can help in filling full-time, part-time, or consulting positions. Both members and nonmembers may use the service for renewable four-month terms. Anonymity will be maintained if requested by the user.

Call HFES at (310) 394-1811 or fax (310) 394-2410 to obtain rates and application forms.

Human Factors and Ergonomics Society Fellows Elected

Three distinguished nominees were recently elected Fellows of the Human Factors and Ergonomics Society. Joining the Society's other 216 Fellows are:

Philip L. Ackerman, Professor, Department of Psychology, University of Minnesota, Minneapolis, MN.

Alvah C. Bittner, Jr., Senior Research Scientist, Battelle Human Affairs Research Center, Seattle, WA.

Deborah A. Boehm-Davis, Associate Professor, Department of Psychology, George Mason University, Fairfax, VA.

Fellow status requires a minimum of five years of membership, ten years of professional experience in the field, outstanding and demonstrable contributions to human factors, three years of direction or supervision of significant human factors efforts, and at least one year's service to the Society.

Calendar

March 16-20, 1994
San Antonio, TX, USA
EDRA 25, the 25th Annual Meeting of the Environmental Design Research Association. Contact EDRA Business Office, P.O. Box 24083, Oklahoma City, OK 73214; (405) 843-4863.

April 7-8, 1994
Washington, DC, USA
1st Automation Technology and Human Performance Conference. Contact Mustapha Mouloua, Cognitive Science Labs, Catholic University of America, Washington, DC 20064; (202) 319-5825.

April 19-22, 1994
University of Warwick, UK
Ergonomics Society Annual Conference. Contact Conference Manager, Devonshire House, Devonshire Sq., Loughborough, Leichestershire LE11 3DW, UK; (44) 509-234904.

April 24-28, 1994
Boston, MA, USA
CHI '94: Association for Computing Machinery on Human Factors in Computing Systems. Contact Thomas Hewett, Drexel University, Dept. of Psychology/Sociology/Anthropology, Central Receiving, 33rd & Ludlow Sts., Philadelphia, PA 19104; (215) 590-8616.

May 8-12, 1994
San Antonio, TX, USA
Aerospace Medical Association 65th Annual Scientific Meeting. Contact Pamela Day, Aerospace Medical Association, 320 S. Henry St., Alexandria, VA 22314; (703) 739-2240.

May 21-25, 1994
Washington, DC, USA
Association for the Advancement of Medical Instrumentation 29th Annual Meeting and Exposition. Contact AAMI Education Department, 2220 Washington Blvd., Suite 400, Arlington, VA 22201-4598; (703) 525-4890, fax (703) 276-0793.

May 23-27, 1994
Dayton, OH, USA
NAECON '94, National Aerospace and Electronics Conference. Contact NAECON '94, P.O. Box 31341, Dayton, OH 45431-0341, or call Thomas J. Gaudian, (513) 427-4267, fax (513) 427-4675.

June 7-10, 1994
San Antonio, TX, USA
Industrial Ergonomics and Safety Conference. Contact F. Aghazadeh, IMSE Department, Louisiana State University, Baton Rouge, LA 70803; (504) 388-5367, fax (504) 388-5990.

June 12-17, 1994
San Jose, CA, USA
SID '94, Society for Information Display International Symposium, Seminar, and Exhibition. Contact Joyce E. Farrell, SID '94 Conference Chair, Hewlett-Packard Labs, P.O. Box 10490, Palo Alto, CA 94303-0969; (415) 857-2807, fax (415) 857-4320.

July 6-8, 1994
Manchester, UK
4th International Conference on Human Aspects of Advanced Manufacturing and Hybrid Automation. Contact Paul Kidd, Cheshire Henbury Research and Consultancy, Tamworth House, P.O. Box 103, Macclesfield, SK11 8UW, UK; (44) 625-619-313, (44) 625-619-060.

August 2-6, 1994
St. Petersburg, Russia
East-West International Conference on HCI. Contact Claus Unger, Praktische Informatik II, Fernuniversitat, Feithstr. 140, D-58084 Hagen, Germany, or Email ewinfo.chi@xerox.com.

August 15-19, 1994
Toronto, Canada
12th Triennial Congress of the International Ergonomics Association. Contact IEA '94 Secretariat, c/o JPdL Multi Management Inc., Toronto Dominion Center, 55 King St. W, #2550, Toronto, ON, Canada M5K IE7; (416) 784-9336, fax (416) 784-0808.

Notices for the calendar should be sent at least four months in advance to:
CSERIAC Gateway Calendar, AL/CFH/CSERIAC Bldg 248, 2255 H Street, Wright-Patterson AFB OH 45433-7022

Human Engineering Division, Armstrong Laboratory Colloquium Series
The Eyes: Reflector of Attentional Processes

John A. Stern
Synopsis by June J. Skelly

Editor's Note: Following is a synopsis of a presentation by Dr. John A. Stern, as the third speaker in the 1993 Human Engineering Division, Armstrong Laboratory Colloquium Series: The Human-Computer Interface. This synopsis was prepared by Dr. June J. Skelly, Research Psychologist with the Crew Systems Integration Branch, Human Engineering Division, Armstrong Laboratory. JAL

Dr. John Stern introduced his discussion topic by posing the question: Why should we, as human factors researchers, be interested in assessing the gaze control system? While it is acknowledged that the gaze control system functions to acquire information, it is unlikely that few of us have entertained the idea that this system could also provide information about *how* we process this information. Dr. Stern maintains that the gaze control system (eyes, head, and body) may in fact, be an important source for providing valuable information regarding an operator's level of attention, alertness, and fatigue.

In our high-tech environments, operators spend more time monitoring rather than operating equipment. With current technology, the likelihood of equipment malfunction is small. With infrequent need on the part of operators to intervene, their task has become a *vigilance* task. Vigilance tasks are, by definition, tasks requiring sustained attention but with little need to perform specific operator functions. The prevailing assumption has been that the operator will adjust to changes in task requirements when necessary, continuing to perform efficiently. According to Dr. Stern, that assumption now has to be challenged. He noted that it has been well documented that the human operator does not perform such monitoring functions reliably, and that time-on-task (TOT) is a major component of performance decrements. Human error appears more and more frequently to be a major contributor to fatal accidents and near misses in the aviation environment. What can be done to improve this picture?

Dr. Stern suggests that a fruitful approach to investigating questions of performance decrements in long duration tasks, would be to monitor the operator for alterations in attention to the assigned task. He argues that one could then take corrective action of one kind or another when vigilance wanes, hopefully before important events are missed. This approach requires that we conceive of the operator as an important component of the system. Dr. Stern concluded his introduction by proposing that investigations of our gaze control system should be an important part of "system evaluations."

During the remainder of his presentation, Dr. Stern discussed evaluating gaze control system components, and how we might use this information to ascertain an operator's level of attention and fatigue He limited his discussion topics to head and eye movement research, noting that investigations of the body (e.g., orientation and locomotion) have not been the focus of his own research.

Gaze Control and Attention and Fatigue Processes

Head Movements

By way of introducing this research, Dr. Stern began by asking the audience to think about the meaning of the word "democracy." He asked the group whether they had noticed making either a head movement or shifting their gaze while pondering the meaning of "democracy;" most did not. Yet, Dr. Stern reported that he had observed this behavior in our group. In fact, naturalistic observations have shown that people typically move their head or their eyes when thinking. For example, observations of young inexperienced readers show they are more likely to make head movements than adults. This is also the case in experimental situations; adults will typically make head movements when reading aloud, but not when reading silently. Head movements are also likely to occur when reading difficult text as compared to easy text.

The timing of head movements with respect to the eye also appears to reveal aspects of information predictability. For example, in laboratory situations, Dr. Stern and his colleagues have shown that in a search task when stimulus position is cued, the head will move, on average, 100 ms *ahead* of an eye movement to the periphery. However, in an uncued situation, the head lags 30-60 ms *behind* a saccadic eye movement when acquiring a peripheral target. Thus, head movements made to acquire information also tell us a great deal about the process itself.

Eye Movements

By far, eye movements are Dr. Stern's favorite research topic and by way of introducing this aspect of the gaze control system, he gave an example of how we can make some inferences about an individual's information processing style by naturalistic observation. For example, if asked to spell the word *mother* backwards, some individuals will make a lateral eye movement to the left and others will shift their gaze to the right. Those individuals that shift gaze to the left appear to be able to visualize the word *mother* and then simply read off the letters R-E-H-T-O-M, while those that shift their gaze to the right appear to rely on

Continued on page 8

auditory or other symbolic strategies, such as repeating the word "mother, mother, mother..." until spelling is complete. Lateral eye movements are but one aspect of eye movements that have been shown to be affected by cognitive and TOT processes.

Dr. Stern's pioneering research investigating the eye blink has shown eye blinks do not occur at random. Blink frequency, latency, and duration have been shown to be affected by cognitive demands and TOT. We blink when we can take "time out" from processing. For example, when required to commit information to memory, blink latency increases as the number of items to be committed to memory increases. Pupillary dilation is also significantly related to the number of items in a memory set as well; the higher the cognitive demands, the greater the increase in pupillary dilation. Blink frequency and blink duration also reflect attentional demands in an operational situation. For example, B-52 pilots in a simulated long-duration mission blinked significantly less than their copilots. However, when pilots and copilots reversed roles, their pattern of eye blinks reversed as well. That is, pilots assuming a copilot role blinked more frequently than copilots that now assumed pilot responsibilities. Eye blink duration was also affected by high attentional demands. In this same study, individuals assuming pilot responsibilities exhibited shorter duration eye blinks than those in the copilot role. These changes were attributable to the task demands and not to the individual.

Dr. Stern's research has also shown that eye blink measures can provide valuable information about TOT effects. In vigilance situations, most tasks of concern involve visual stimuli. Therefore, if the eyes are closed while we are supposed to be taking in information, such information is missed. Further, if the eyes are open and immobile for long periods of time when scanning is required, once again we would suspect that vigilance is compromised. There is in fact, a large literature of experimental results demonstrating that blink frequency increases as a function of TOT. One example of TOT effects is the appearance of blink flurries, a series of eye blinks occurring in rapid succession. Blink flurries often occur after the eyes have been immobile for a period of time. It is thus not outside the realm of possibility that the increase in blink frequency as a function of TOT may be associated with "attentional drop-outs" and hence, lapses in vigilance. Dr. Stern suggests that analysis of specific head and eye movement relationships can provide valuable information regarding an operator's ability to maintain a vigilant state.

Gaze Control and a Simulated Air Traffic Control Study

During the final segment of his presentation, Dr. Stern presented data from a recent study designed to examine changes in the gaze control of operators as a function of TOT.

The data were obtained during a simulated air traffic control task. Subjects performed the task in two-hours sessions each, on three separate occasions, for a total of six

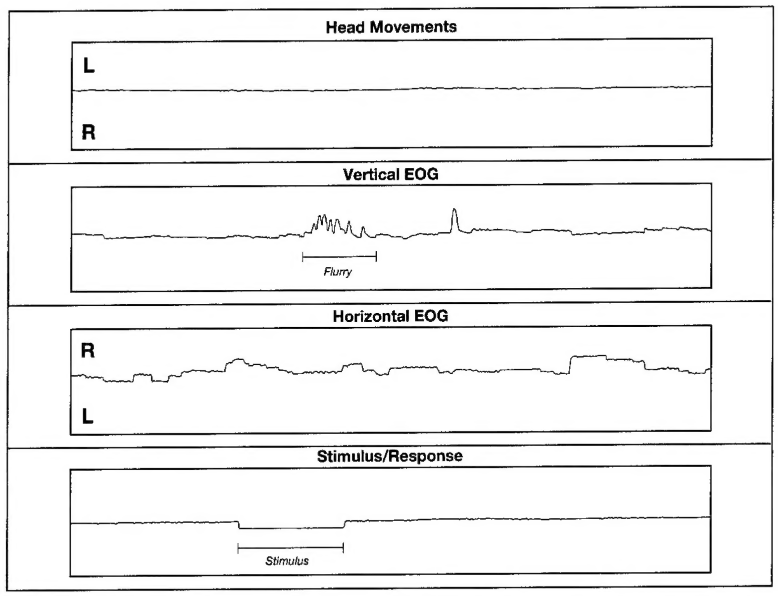

Figure 1 (a). A flurry of blinks in response to a critical stimulus event indicating a re-alerting of the attentional system.

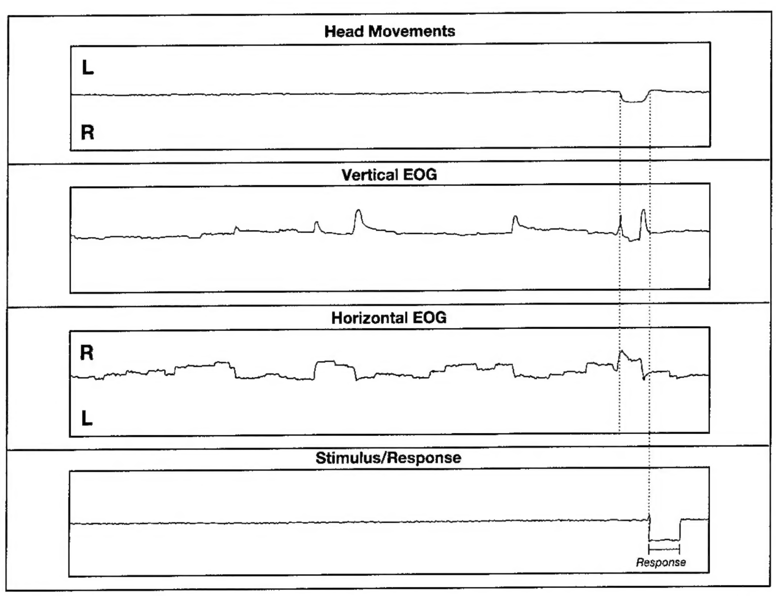

Figure 1 (b). An example of a time-locked gaze control component associated with efficient visual processing.

hours. The task involved monitoring a CRT where two vectors oriented from the lower right to upper left each carried eight aircraft to be monitored. During each of the two-hour test periods there were 44 "unexpected" events that occurred requiring operator action. These events were of three types: (1) two aircraft flying at the same altitude, (2) aircraft flying outside of a vector, and (3) loss of altitude information presented for an aircraft.

Head movements were recorded using a photoelectric device. Eye movements in the horizontal and vertical planes were recorded using electro-oculographic measures (the EOG is not a measure of muscle activity but reflects, it is believed, changes in the potential difference between the retina and cornea as the latter shifts in two-dimensional space). Blink measures abstracted during operator performance included blink rate as a function of TOT, blink amplitude, blink duration, and saccadic eye movements measured per unit time to determine amount of search being done by the operator. It was expected that saccade frequency would decrease over time. In addition to these measures, the timing relationships between blinks and saccades were measured. In Dr. Stern's opinion, an alert system will show blinks and saccades to be tightly time-locked, since there can be no visual intake during either a blink or a saccade. An example of such time locking is shown in Figure 1, panels (a) and (b). In panel (a) we see the subject has been alerted to a critical stimulus event that requires a complex decision and appropriate input response. Note the flurry of blinks occurring near the end of the stimulus event. Figure 1 (b) shows a continuation of this record. Here, just prior to response input, we see an example of head movement, eye blinks, and saccadic time-locking. Notice that as the head shifts to the right there are concomitant blinks and saccadic activity to the right. Then, immediately before response input, the head readjusts, returns to position, and the eye makes a compensatory saccade. During this time no visual intake can occur. Thus, this tight time-locking of head and eye movements is an efficient way for the system to reduce visual intake "down time."

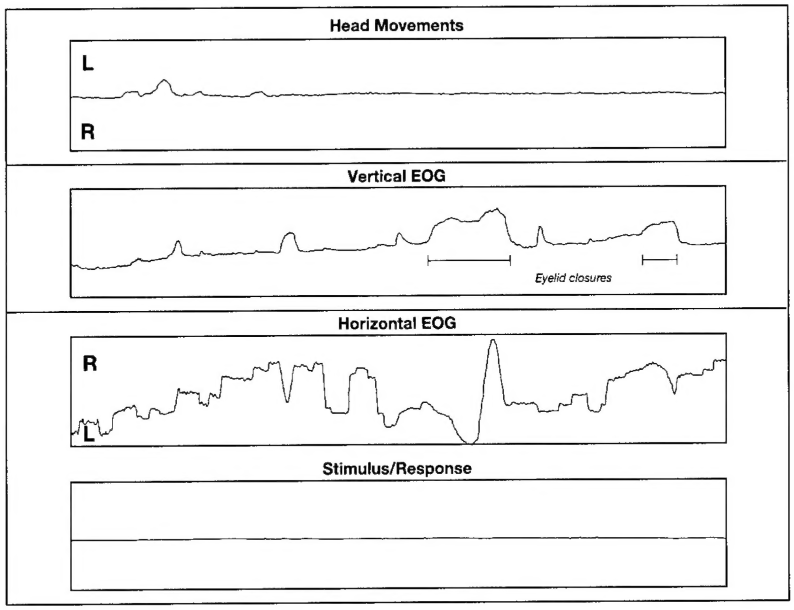

Figure 2. A pattern of eye and head movements associated with a low vigilant state.

However, as an operator begins to tire (prior to any noticeable performance decrement), Dr. Stern reasons that one should see an emerging pattern of decoupling between blinks and saccades. Figure 2 shows an example of an "attentional dropout" period as a function of TOT.

In this record we see the subject's head begin to wobble, followed by long closure duration blinks and then full eyelid closures. The horizontal EOG channel indicates that an efficient saccadic scan pattern (see Fig. 1) has been replaced by the eyes making large excursions in both directions. It is highly unlikely that this subject would have picked up a critical stimulus event had one occurred during this time frame.

Experimental Results

Results of this simulated air traffic control study showed that blink measures did indicate a number of significant TOT effects. Blink rate showed a significant increase over time, as was also true for the occurrence of blink flurries (defined as a minimum of three blinks occurring in a three sec-

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Table 1.
Significant Changes in Blink Measures as a Function of Time-on-Task (TOT).

Measure	Significance Level
Blink Rate (increase)	$p < .0008$
Frequency of Blink Flurries (increase)	$p < .01$
Blink Duration (increase)	$p < .03$
Saccade Rate (decrease)	$p < .0004$
Fixation Duration (increase)	$p < .04$
Saccade Amplitude (decrease)	$p < .0000$

ond period). As predicted, saccade rate decreased as a function of TOT. Long duration fixation pauses (in excess of 2 seconds) increased over time suggesting that as fixation duration increased there was also less scanning by the subject as indicated by the decrease in saccade rate. These data are summarized in Table 1.

Summarizing, Dr. Stern noted that these are but a few examples demonstrating how information from biological measures might be used to make inferences about the operator's "state" or ability to respond to infrequently occurring events. These aspects of the gaze control system can be especially useful for the evaluation of equipment operators, especially those individual who utilize visual input as a major source of information on which action must be taken. ●

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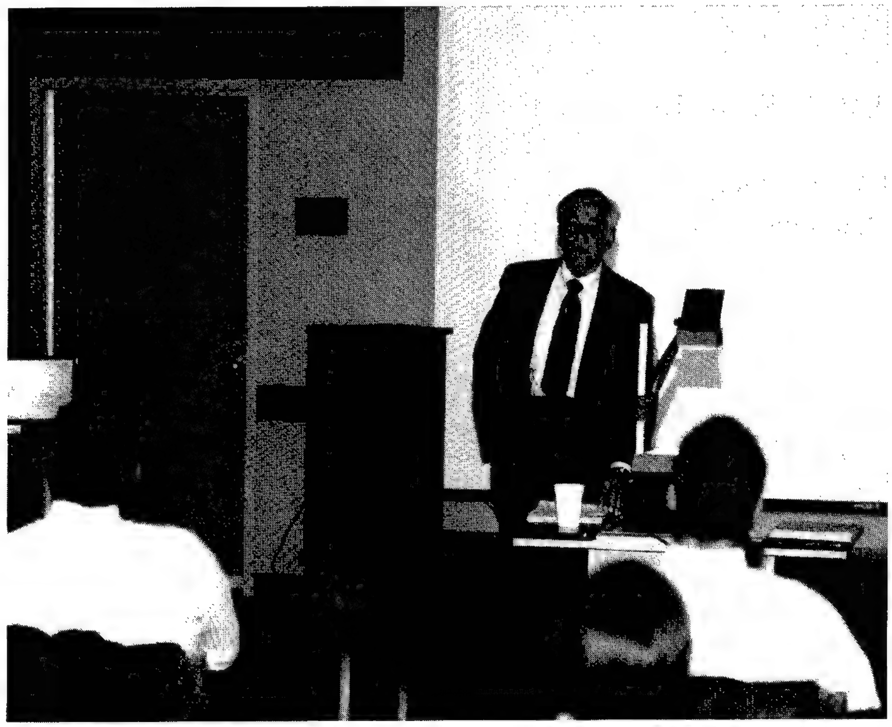
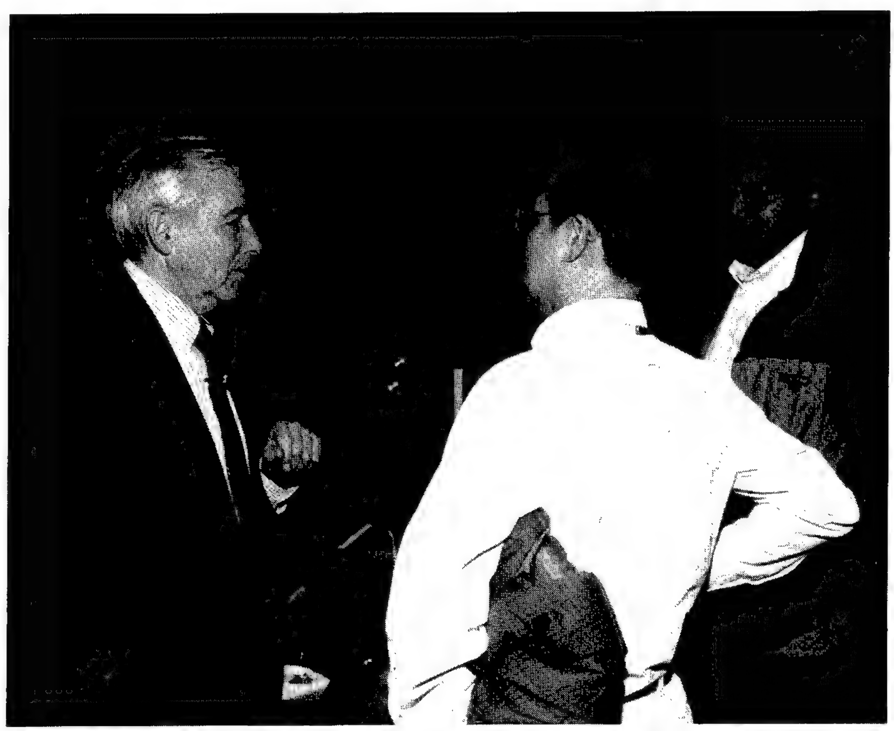
Scenes from the Human Engineering Division, Armstrong Laboratory Colloquium Series:



Dr. Stern stressed the point that the gaze control system provides vital information about one's level of attention.



Following his presentation, Dr. Stern spoke with several vision scientists from the Human Engineering Division of Armstrong Laboratory.

Human Engineering Division, Armstrong Laboratory Colloquium Series

A Conversation with John Stern

Reuben L. Hann

Editor's Note: The following is an edited transcript of a conversation with Dr. John A. Stern, Washington University, who had just made a presentation as the third speaker in the 1993 Human Engineering Division, Armstrong Laboratory Colloquium Series: The Human-Computer Interface. The interviewer was Dr. Lew Hann, CSERIAC COTR. JAL

CSERIAC: You used to be involved in studies using brain wave recording [EEG] techniques; how did you get interested in the area of eye blink measures?

Dr. Stern: I was doing some EEG studies for the Army aviation people. They were concerned about the possibility of inducing seizures, due to the stroboscopic effect of helicopter rotor blades breaking up sunlight. We demonstrated to them that it would not be a problem; but in the process of collecting in-flight data, an aviation psychologist colleague and I noticed that the pilots, who were in transition/ training to fly larger helicopters, hardly ever moved their heads. We decided to find out what they were doing with their eyes during flight activity. We developed eye movement amplifiers and started recording in the helicopter. That's what got me started looking at what people do with their eyes as they process information.

CSERIAC: Why the eyeblink in particular?

Dr. Stern: Well, as we did our average evoked-response studies, we found people frequently blinked at the point in time when we were most interested in extracting information, which contaminated the results. The eyeblink signals were considered noise, or artifact. So I thought, instead of telling people not to blink, why not study the blink itself—since it seemed to occur during points in time associated with the processing of information. In other words, we used "noise" as signal. That's how we got interested in the timing of eye blinks.

CSERIAC: A colleague said that you sometimes refer to the eyeblink as "the brain's exclamation point". Could you explain that?

Dr. Stern: It's an exclamation point in terms of—here's a point in time where you can take a brief rest, where you can take time out from taking in or processing information. In that sense, it's an exclamation mark. It indexes a specific event with respect to the processing of information.

CSERIAC: During your presentation you referenced the earlier pupillary response work of Beatty. I remember that years ago there was a flurry of research examining the pupillary response in a variety of settings; the result was that it ended up being correlated with a whole variety of behavioral processes. There was criticism by someone at the time that it correlated with "just about everything," and was therefore of questionable value in inferring internal psychological events. Apparently it has found new respect since then.

Dr. Stern: The earliest work using pupil dilation was by Eckhardt Hess, who used it to study *affect*. It was his conviction that pupillary dilation was associated with positive affect, constriction with negative. The problem was that he used pictures as the stimuli, with no control for the amount of light impinging on the eye. Beatty's work was important because he removed that potential confound by presenting the stimuli auditorily. The pupillary response then is a reflector of what is going on inside, rather than a reflector of what is coming in.

CSERIAC: When you worked for the CIA, were you trying to use eyeblink as a kind of "lie detector"?

Dr. Stern: Yes, we've done some work looking at what happens when people are required to tell a lie, and to see if can we use information from the eyes to infer about whether they are answering truthfully or deceptively. As you may know, the common polygraph technique assumes that lying is associated with affective arousal, and the polygraph gives some sort of index of the arousal associated with lying. We reasoned that if you are required to lie, you are required to more thoroughly process information cognitively. So what we looked at was the nature of eye movements as people were acquiring information. They read a question on a CRT. We could identify when they had finished reading the question, and we looked at the eye movements between that point and the onset of answering the question. It discriminated nicely between answering deceptively and answering truthfully.

"It may be better to build redundancy into the equipment, since humans do such a poor job at maintaining vigilance; putting two computers in tandem may be more reasonable than having a human in the system."

CSERIAC: You mentioned the phenomenon of lateral eye movement

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when persons were involved in cognitive activity — that some persons looked left, others right.

Dr. Stern: This lateral eye movement phenomenon is interesting. There was some research in this area in the 1970s, and then it disappeared. There were attempts to relate lateral eye movement to whether you were processing with the right or left hemisphere. It turned out to be nonsense. But the fact is, if you ask 100 people a series of 20 to 30 questions, while watching their eye movements associated with taking in the question and before responding, about one-third will move their eyes to the left, one-third will be right-movers, and one-third will be indeterminate. So it's not a normal distribution, it's rectilinear.

CSERIAC: What do these eye movements tell you about the person?

Dr. Stern: Persons who are left-movers are more likely to form a mental picture as they read text; they do not "see" the words, but rather a vivid mental image is formed. These persons are more likely to prefer highly descriptive novels, by the way. But the question is, why does one person develop one strategy, and another person develops a different one? And how do these strategies affect our ability to learn? For instance, I knew a student who had severe "math anxiety." This person had a very difficult time doing mental arithmetic. It turned out that she was a left-mover who visualized everything. This is not the optimum strategy for such cognitive tasks. When she was taught some tricks which did not involve visualization, she found the task much easier. Apparently her teachers were visualizers and taught that strategy to kids learning arithmetic. If she'd had a teacher who was aware of the fact that some kids don't learn well with this strategy, she might not have developed all these anxieties. So it is important to know that not everyone solves problems the same way.

CSERIAC: If the population is really composed of two kinds of "processors," what implications might that have for the design of human-machine interfaces?

Dr. Stern: Not only the design, but also the selection of people to operate the equipment–there are two ways to look at it. Let me tell you an anecdote. We were doing some work in a flight simulator, looking at pilots flying with information presented on the helmet visor. We were observing their head movements as they operated, and what was interesting to me was the frequency with which they looked down at a conventional paper map in a holder attached to their knee. Some looked at the map, and apparently formed an internal representation, because they did not have to look again for minutes. Others had to continually refer back to the map, because they could not retain the image. So there are marked individual differences with respect to these abilities.

CSERIAC: Should there be a screening process to differentiate individuals, based on this kind of skill?

Dr. Stern: Well, the question I have is, can people be trained to be more attentive to these visual cues? Can persons who are poor visualizers be trained? If they can, then selection would not be necessary.

CSERIAC: One of CSERIAC's missions is to expedite the transfer of information from the research laboratory to the field. Do you have any thoughts about this process?

Dr. Stern: Well, the way scientists retrieve information from the literature is, I'm sure, also applied by the engineering world. But they may be looking at the wrong literature. It seems that the engineers of today should be concerned with issues of the effect of humans being out of the loop on their ability to deal with problems which occur with the in-the-loop equipment. They ought to become concerned with issues of the effect of our new technology on the human's ability to deal with that technology.

CSERIAC: One of our related human factors organizations has an interesting motto: "There are no unmanned systems."

Dr. Stern: Humans have to be there–at least to monitor. Things go wrong frequently enough for them to have to intervene. But the fact is, computer-controlled equipment is becoming increasingly reliable, so the likelihood that a person will be called upon is decreasing. It may well be that 10 years from now airplanes will fly without pilots. It may be better to build redundancy into the equipment, since humans do such a poor job at maintaining vigilance; putting two computers in tandem may be more reasonable than having a human in the system. To many, that's heresy, but I can see that happening. Consider the issue of humans in space, and what has been contributed by putting humans-in-space, rather than sending equipment up to perform the functions. Much of the humans-in-space effort has been because the Russians have done it—because it has popular appeal, and helps to sell the space program. If you simply send equipment up, it doesn't have that appeal. In the future, humans will not only be out of the loop, they won't even *be* there.

CSERIAC: Surely there will be a human in the loop somewhere?

Dr. Stern: Oh yes. But you can take over control from the ground as well as in the air.

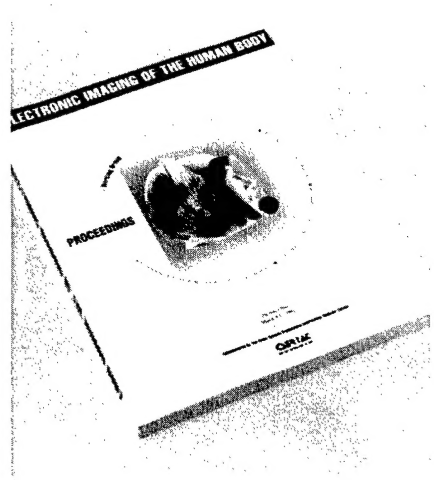
CSERIAC: There is the problem of trusting the hardware, though.

Dr. Stern: Right. But think about what pilots are permitted to do on trans-Atlantic flights. They are now allowed to take naps, as long as one crew member is awake. I'm not sure how alert that one is, who is awake. There are frightening examples. Look at the frequency with which tankers collide on the high sea in clear weather. They have radar systems available; the human is looking at the display, but doesn't see the other ship. It seems that the technology is available where, if another object is moving out there, you can alert personnel, without requiring someone to see it. You can simply inform the crew that, for example, if no action is taken, there will be a collision in 15 minutes. The same thing is true for aircraft, but the time scale is considerably compressed, of course. If your eyes close for three seconds, and you are closing with someone, you have a major problem. ●

Proceedings of the Working Group on Electronic Imaging of the Human Body

Jennifer Whitestone

The Human Engineering Division, Armstrong Laboratory, in cooperation with the Mallinckrodt Institute of Radiology; the Washington University School of Medicine; and the Lister-Hill National Center for Biomedical Communication, National Library of Medicine, hosted the first annual meeting of the Cooperative Working Group on Electronic Imaging of the Human Body. The working group, under the auspices of CSERIAC, brought together 31 researchers from government, industry, and academia working in the area of medical imaging and, more generally, image science, to discuss issues associated with collecting, archiving, transferring, visualizing, and analyzing image data. Although applications for three-dimensional (3-D) human body image data range from reconstructive surgery to designing protective equipment, the challenges faced by medical researchers, anthropometrists, educators, prosthodontists, and design engineers are the same: How can the images be captured quickly and accurately? Can the data be reduced to a manageable size for archiving, manipulating, and visualizing? How can the images be represented in an efficient, yet lossless format to allow for meaningful and timely analyses? What software tools and filters are available for handling the data? What databases of human body images currently exist and how can these images be made accessible to other researchers and physicians? What standards exist for image data and what methods or filters are available for implementing these standards? This working group has encouraged effective use of the resources from all the various disciplines involved in electronic imaging of the human body, identified immediate challenges associated with handling image data, and developed strategies for applications relevant to engineering, medicine, entertainment, and education. To address image data compatibility across numerous platforms and with applications software, this multi-disciplinary group will continue to provide direction for data format standards that will impact future industry standards.



Electronic Imaging of the Human Body (1993).

Five topic areas were identified to assist in categorizing the position papers offered by each of the working group members. These areas include (1) development of surface scanning systems, (2) data storage and interchange format standards, (3) calibration, validation, and evaluation of scanning systems, (4) data analysis, image processing, and display, and (5) physically based modeling of deformable objects. The *Proceedings*, available through CSERIAC for $35, offer a brief overview of the progress and issues associated with each of these topic areas and provide a compilation of the position papers submitted by each of the 23 speakers.

Computer networks have revolutionized exchange and distribution of visualization technology in the form of "collaboratories." Collaboratories, a combination of the term "collaboration" and "laboratories," are an electronic extension of independent laboratories containing hardware, software, people, and databases, but are not limited to a physical space. Collaboratories can, in fact, contain many independent laboratories which are not collocated, but are connected electronically. The use of these networked relationships makes possible the effectiveness of this working group to initiate and continue electronic communication to support the objectives of this group. ●

Jennifer Whitestone is a Biomedical Engineer with the Design Technology Branch, Human Engineering Division, Armstrong Laboratory, Wright-Patterson Air Force Base, OH.

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INFORUM®

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Leo J. D. Bernier

INFORUM is a revolutionary groupware system that improves the process of collecting information and forming consensus. As mundane as this activity may sound, it is fundamental to the way we conduct business today. It has been estimated that, in the Department of Defense (DoD) alone, such activities carry a price tag of more than $6 billion annually!

These numbers are in fact conservative, especially as we begin to account for the industrial base that supports the DoD. Consider, for example, end-users of new and existing systems. These individuals (and there are many of them) spend a considerable amount of time collecting information and forming consensus on the intended purpose of their systems, the goals of these systems, and the requirements of the systems. End-users are also involved in communicating these requirements to system designers and in assessing the design and implementation against the original set of requirements.

Human factors personnel are an important class of experts who must interact with end users. These experts spend a significant amount of time setting human resource goals that support end-user goals and in refining (from a human resource perspective) the broad requirements provided by the end-users. These experts also participate in communicating these more detailed requirements to the system implementors. In addition, human factors experts may interact with human resource specialists to prepare a human resource capability that can effectively support the system being developed or modified. Once again, in performing these activities, considerable time and effort are involved in collecting information and forming consensus.

Not only are such activities pervasive in business today, methods and tools needed to support these activities are only now beginning to appear in the marketplace. INFORUM is one such tool.

Like other automated collection and consensus building systems, INFORUM replaces the more conventional forms of collecting information. These include questionnaires that are administered manually, live interviews, and group meetings. Each of these methods has unique strengths and weaknesses, but all share the common weakness of being inconvenient and costly to implement. Recognizing the opportunity to improve this situation, software developers have begun to provide automated alternatives.

INFORUM is unique in that it offers automated alternatives to all three manual methods cited. It can be configured and used in live data collection sessions with either groups or individuals, it can support data collection activities via a local area network, *and* it can manage the collection of information from individuals at remote sites by means of its Electronic Questionnaire.

One way INFORUM distinguishes itself from other similar tools in the marketplace is that it can be used as a different time/different place system (see Fig. 1). This means that individuals participating in a data collection and consensus building activity need not be physically located in the same place and can participate at different times. Most other systems are same time/same place. This feature of INFORUM permits great flexibility in scheduling the involvement of individuals and virtually eliminates the expense (and the aggravation) normally associated with traveling to the data collection site. The bottom line is that broader participation is possible at a lower cost.

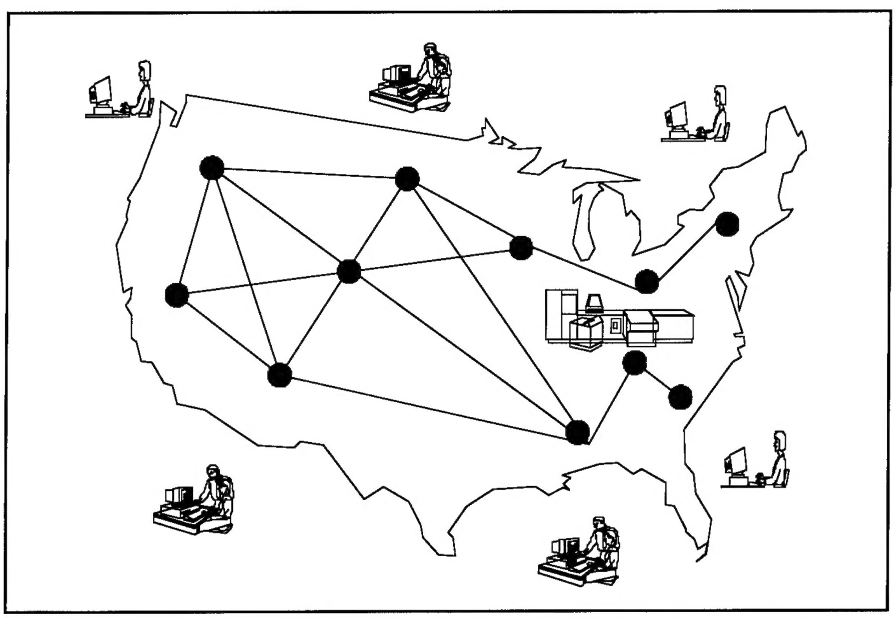

Figure 1. INFORUM allows for data collection in a variety of locations at different times without travel to the data collection sites.

Another feature that distinguishes INFORUM is its ability to collect information from multiple viewpoints simultaneously on an interrelated set of topics. For example, let's assume that the system's functions, goals, and requirements are defined by the end-users. INFORUM could easily be configured to collect this information from all the end users and to form consensus among them. Next, assume that a design team representing different functional areas, such as human factors, wishes to extend the requirements and form an initial specification. INFORUM could easily be configured to collect this information. It could also be used to correlate the information provided by the design team with similar information provided by the end users. INFORUM could then be used to prioritize the requirements and specifications from the point of view of the design team or from the point of view of the end users. Similarly, INFORUM could be configured to permit the development team to detail the specifications and form an implementation plan. Collecting and managing information in this manner also permits complete traceability of information between the viewpoints (end users, the design team, and the implementors of systems).

This is just one example of how INFORUM might be applied. The point to remember is that INFORUM can be configured to collect any information, for any purpose, from any combination of viewpoints. This group of features sets INFORUM apart from other data collection and consensus building systems currently in the marketplace.

INFORUM has also been designed to interface easily with existing applications. This means that it can be used, for example, to collect information to support any number of existing human factors computational models. INFORUM can also import the results generated by these applications and then use them to support still other analyses.

INFORUM is currently being used to support a variety of data collection activities, such as collecting and managing suggestions, user requirements, modeling information, user feedback, and strategic planning information. In one effort, INFORUM is being used to develop a *Human Resource Guide and Career Development Handbook* for a large organization. In another effort, a software company is using it to collect user reaction to its product line. In yet another effort, INFORUM is being used to create a set of information standards. If there is a need to collect information and form consensus, there is probably an opportunity to use INFORUM.

INFORUM is written in CLIPPER 5.01 and is designed to run on any system that supports DOS 3.3 or higher. The system is being developed under a Small Business Innovation Research Program initiative for the Computer Resource Technology Transition Program managed by the Systems and Software Design Center, part of the Electronic Systems Center of the Air Force Materiel Command.

For further information about INFORUM, please contact Michael O'Neill at Bernier & Associates, Inc., 458 Boston St., Topsfield, MA 01983. Telephone: (508) 887-8683, Fax: (508) 887-6592, E-mail: ljb@world.std.com ●

Leo J. D. Bernier is President of Bernier & Associates, Topsfield, MA.

Editor's Note: In the last issue of Gateway, we inadvertantly used an out-of-date photograph in the SCOPE ad (below). We have corrected that and offer our apologies to the U.S. Army Research Laboratory. JAL

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